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Enhancing mental models for team effectiveness

Marie-Eve Jobidon

Alexandra Muller-Gass

Matthew Duncan

Ann-Renee Blais

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Technical Report
DRDC Toronto TR 2009-202
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Principal Author

Original signed by Marie-Eve Jobidon

Marie-Eve Jobidon

Defence Scientist, Socio-Cognitive Systems Section

Approved by

Original signed by Keith Stewart

Keith Stewart

Head, Socio-Cognitive Systems Section

Approved for release by

Original signed by Dr. Stergios Stergiopoulos

Dr. Stergios Stergiopoulos

Acting Chair, Knowledge and Information Management Committee

Acting Chief Scientist

In conducting the research described in this report, the investigators adhered to the policies and procedures set out in the Tri-Council Policy Statement: Ethical conduct for research involving humans, National Council on Ethics in Human Research, Ottawa, 1998 as issued jointly by the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada.

Abstract

The success of Canadian Forces operations relies on team members working cooperatively towards shared goals. It is commonly recognized that some form of shared knowledge contributes positively to team functioning, and as such the concept of team mental models (TMM) has been the focus of many research endeavours (e.g., Edwards et al., 2006; Marks et al., 2002; Mathieu et al., 2010). The purpose of this study was to investigate whether enhancing TMM, more specifically, task models (knowledge on task procedures and strategies, potential contingencies and environmental constraints) and team interaction models (knowledge about roles and responsibilities, role interdependencies, information flow, etc.), improved team processes and performance in dynamic situations. Fifty-four participants took part in this study, for a total of 27 two-person teams. C^3Fire, a simulation of forest firefighting, was used as the task environment. Each team was assigned to one of three learning conditions meant to manipulate TMM: task (additional information on environmental dynamics pertinent to the firefighting task), team (additional information on the roles of each team member and possible interaction strategies) and control (no additional information). Task complexity was varied through transparency of courses of action (COA) to investigate whether it moderates the effect of TMM on team effectiveness. Measures of team performance and team processes were gathered. The results showed that the manipulation of task complexity was successful: better performance and coordination were observed in conditions with a more obvious COA. However, there was no significant effect of learning condition on team effectiveness. This study was a first attempt at investigating the effect of enhancing TMM on team effectiveness. Unfortunately, we can draw only limited conclusions as to the impact of additional pre-experimental information about the task or team interaction on team functioning. Future plans could include making task and team interaction conditions more distinctive, and adding a measure of team knowledge or mental models to gather valuable information on the content of TMM, and to allow a better assessment of any change in the models following the experimental manipulation.

Résumé

Le succès des opérations des Forces canadiennes repose sur la capacité des membres de l’équipe à travailler ensemble vers des buts communs. Il est largement reconnu que certaines formes de connaissances communes ont des effets positifs sur le fonctionnement d’une équipe. C’est pourquoi le concept de « modèles mentaux communs » (MMC) a fait l’objet de nombreuses recherches (p. ex., Edwards et coll., 2006; Marks et coll., 2002; Mathieu et coll., 2010). La présente étude a pour but de vérifier si le fait d’améliorer des MMC, plus particulièrement les modèles de tâche (connaissances des procédures et des stratégies associées à une tâche donnée, des imprévus et des contraintes environnementales) et les modèles d’interaction (connaissances des rôles et responsabilités, des interdépendances des rôles, de la circulation de l’information, etc.), contribue à l’amélioration des processus et du rendement collectifs dans des situations dynamiques. Les 54 participants ont été divisés en 27 équipes de deux personnes. C^3Fire, un simulateur de lutte contre les feux de forêt, a été utilisé comme tâche expérimentale. Chacune des

équipes a été affectée à l'une des trois conditions d'apprentissage pouvant influencer un MMC : tâche (plus d'informations sur la dynamique d'une lutte contre un incendie), équipe (plus d'informations sur les rôles de chacun des membres de l'équipe et sur les stratégies d'interaction possibles) et contrôle (aucune information additionnelle). La complexité de la tâche a été variée par l'entremise de la transparence des plans d'action afin de déterminer si la complexité modérait les effets des MMC sur l'efficacité collective. Les mesures du rendement et des processus collectifs ont ensuite été recueillies. Les résultats ont révélé que la manipulation de la complexité de la tâche a été fructueuse : un meilleur rendement et une meilleure coordination ont été observés lorsque le plan d'action était plus évident. Par contre, on n'a noté aucun effet de la condition d'apprentissage sur l'efficacité de l'équipe. Cette étude constituait la première tentative visant à déterminer les effets de l'amélioration des MMC sur l'efficacité collective. Malheureusement, les résultats sont peu concluants pour ce qui est des effets de l'ajout de renseignements préexpérimentaux à propos de la tâche ou de l'interaction des membres de l'équipe sur le bon fonctionnement de l'équipe. Il serait intéressant d'inclure dans les futurs travaux de recherche des conditions liées aux tâches et à l'interaction collective plus distinctes et une mesure des connaissances de l'équipe (modèles mentaux) de manière à amasser des données utiles sur le contenu des MMC et d'être en mesure de mieux évaluer tout changement apporté aux modèles à la suite d'une manipulation expérimentale.

Executive summary

Enhancing mental models for team effectiveness:

Marie-Eve Jobidon; DRDC Toronto TR 2009-202; Defence R&D Canada – Toronto; September 2011.

Introduction: Teamwork is an integral part of Canadian Forces (CF) operations. The complex and time-sensitive nature of these operations put high demands on teams, which must work cooperatively towards shared goals in order to achieve mission success. It is commonly recognized that some form of shared knowledge contributes positively to team functioning, and as such the concept of team mental models has been the focus of many research endeavours.

Team mental models (TMM) can be defined as structures of knowledge held by members of a team that are developed to describe, explain, and predict their environment, and, consequently, allow them to coordinate their activities, interact with each other and with their environment, and adapt their behaviour to demands coming from the task and other team members. The purpose of this study was to investigate whether enhancing TMM, more specifically, task models (knowledge on task procedures and strategies, potential contingencies and environmental constraints) and team interaction models (knowledge about roles and responsibilities, role interdependencies, information flow, etc.), improved team processes and performance in dynamic situations.

Method: Fifty-four adult participants took part in this study, 34 civilians and 20 military, for a total of 27 two-person teams. C^3Fire, a functional simulation of forest firefighting, was used as the task environment. The enhancement of TMM was attempted by subjecting teams to different learning conditions prior to the execution of the task. Each team was assigned to one of three conditions. In the task condition, teams were informed about environmental dynamics that were pertinent to their firefighting task. In the team condition, teams were briefed on the roles of each team member and on possible interaction strategies. These conditions were contrasted with a control condition in which no additional information was provided. Task complexity was varied to investigate whether it moderates the effect of TMM on team effectiveness. This was achieved by manipulating environmental dynamics (wind speed and object ignition), which affect the transparency of courses of action (COA). Measures of team performance and team processes (coordination and communication) were gathered.

Results: The results showed that the manipulation of task complexity was successful: better performance and coordination were observed in conditions associated with a more obvious COA. However, despite the effective task complexity manipulation, the results did not show a significant effect of learning condition on team effectiveness. A trend in the data suggests that teams with additional information on team interaction or task spend more time on communication.

Significance: This study was a first attempt at investigating the effect of enhancing TMM on team effectiveness. Unfortunately, we can draw only limited conclusions as to the impact of additional pre-experimental information about the task or team interaction on team functioning. Whereas the findings may appear to suggest that mental models do not affect team performance

and coordination, many previous empirical studies have shown that various types of mental models have a positive effect on team effectiveness, either directly or mediated through team processes. A more likely explanation for the non-significant findings is that the task and team learning conditions used in this study did not sufficiently enhance the teams' mental models to observe an effect on team effectiveness.

Future plans: Different avenues are possible to improve upon the design and analyses reported herein, including giving more knowledge on task and team interaction to make the conditions more distinctive, and adding a measure of team knowledge or mental models in the design of future studies to gather valuable information on the content of mental models, and to allow a better assessment of any change in the models following the experimental manipulation. Among other aspects, further analyses could be informative regarding communication patterns through analysis of communication content, and on whether there are differences between civilian and military teams with regards to team performance and communication.

Sommaire

Enhancing mental models for team effectiveness:

Marie-Eve Jobidon; DRDC Toronto TR 2009-202; R & D pour la défense Canada – Toronto; Septembre 2011.

Introduction : Le travail d'équipe est un facteur important dans les opérations des Forces canadiennes (FC). La complexité et les délais serrés de ces opérations exigent des efforts énormes de la part des équipes qui y sont attitrées. En effet, les membres de ces équipes doivent travailler en coopération en vue d'atteindre des buts communs qui leur permettront de réussir leur mission. Il est largement reconnu que certaines formes de connaissances communes ont des effets positifs sur le fonctionnement d'une équipe. C'est pourquoi le concept de « modèles mentaux communs » (MMC) a fait l'objet de nombreuses recherches.

Les MMC se définissent par les structures de connaissances que possèdent les membres d'une équipe qui sont élaborées dans le but de décrire, d'expliquer et de prévoir le milieu dans lequel ils évolueront et, conséquemment, de leur permettre de coordonner leurs activités, d'interagir entre eux et avec leur environnement, et d'adapter leur conduite aux exigences découlant de la tâche à exécuter et des autres membres de l'équipe. La présente étude a pour but de vérifier si le fait d'améliorer des MMC, plus particulièrement les modèles de tâche (connaissances des procédures et des stratégies associées à une tâche donnée, des imprévus et des contraintes environnementales) et les modèles d'interaction (connaissances des rôles et responsabilités, des interdépendances des rôles, de la circulation de l'information, etc.), contribue à l'amélioration des processus et du rendement collectifs dans des situations dynamiques.

Méthode : Cinquante-quatre adultes – 34 civils et 20 militaires – ont participé à l'étude, lesquels ont été regroupés en 27 équipes de deux personnes. C^3Fire, un simulateur de lutte contre les feux de forêt, a été utilisé comme tâche expérimentale. L'étude consistait à tenter d'améliorer les MMC en soumettant les équipes à des conditions d'apprentissage différentes avant l'exécution de la tâche. Chacune des équipes a été affectée à l'une des trois conditions d'apprentissage pouvant influencer un MMC. Pour la condition « tâche », les membres de l'équipe ont reçu de l'information sur la dynamique d'une lutte contre un incendie. Pour la condition « équipe », les participants étaient informés au sujet des rôles de chaque membre de l'équipe et des stratégies d'interaction possibles. Les effets de ces conditions ont été comparés avec ceux de la condition « contrôle », qui consistait à ne donner aucun renseignement additionnel. La complexité de la tâche a été variée afin de déterminer si celle-ci modérait les effets des MMC sur l'efficacité collective. Pour ce faire, les dynamiques environnementales (la vitesse du vent et l'inflammabilité) affectant la transparence des plans d'action ont été manipulées. Les mesures du rendement et des processus collectifs ont ensuite été recueillies.

Résultats : Les résultats ont révélé que la manipulation de la complexité de la tâche a été fructueuse : un meilleur rendement et une meilleure coordination ont été observés lorsque le plan d'action était plus évident. Par contre, on n'a noté aucun effet de la condition d'apprentissage sur l'efficacité de l'équipe. Les données semblent cependant révéler que les équipes qui disposent de

plus de renseignements sur l'interaction collective ou la tâche ont tendance à consacrer plus de temps à la communication.

Portée : Cette étude constituait la première tentative visant à déterminer les effets de l'amélioration des MMC sur l'efficacité collective. Malheureusement, les résultats sont peu concluants pour ce qui est des effets de l'ajout de renseignements préexpérimentaux à propos de la tâche ou de l'interaction des membres de l'équipe sur le bon fonctionnement de l'équipe. Bien que les conclusions de l'étude semblent suggérer que les modèles mentaux n'affectent pas le rendement et la coordination de l'équipe, de nombreuses études empiriques ont montré que certains types de modèles mentaux ont un effet positif sur l'efficacité collective, que ce soit de manière directe ou par l'intermédiaire de processus collectifs. Il est probable que les résultats peu concluants obtenus s'expliquent par le fait que la tâche et les conditions d'apprentissage utilisées ne renforçaient pas suffisamment les modèles mentaux des équipes pour que l'on puisse observer un effet sur leur efficacité.

Perspectives : Il y aurait diverses façons d'améliorer le devis expérimental et les analyses rapportés dans le présent document, notamment en donnant aux équipes davantage de renseignements sur la tâche et sur l'interaction collective de manière à rendre les conditions d'apprentissage plus distinctes. Il serait aussi possible d'implanter un système de mesure du savoir collectif dans le cadre d'autres études, ce qui permettrait d'amasser de précieuses informations sur le contenu des modèles mentaux et d'y observer plus concrètement les changements découlant de la manipulation expérimentale. En approfondissant les recherches, il serait notamment possible d'en savoir davantage sur les différents modèles de communication et être en mesure d'établir s'il existe des différences entre les équipes de militaires et celles composées de civils sur le plan du rendement et de la communication.

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1 Introduction

Teamwork is an integral part of Canadian Forces (CF) operations. The complex and time-sensitive nature of these operations put high demands on teams, which must work cooperatively towards shared goals in order to achieve mission success. Teamwork is a process that implies cooperation between a number of people that individually hold only part of the resources, expertise, and knowledge required to execute the task, and have only a partial comprehension of the problem. It is widely accepted that some form of shared knowledge plays a role in the quality of team effectiveness, as defined by team performance and team processes (e.g., Cannon-Bowers, Salas, & Converse, 1993; Edwards, Day, Arthur, & Bell, 2006; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). The concept of team mental models is commonly used in the study of shared knowledge, and has been included in several models and frameworks of team functioning (see, e.g., Salas, Sims, & Burke’s Big Five, 2005; Shanahan, 2001; Tannenbaum, Beard, & Salas, 1992; and more implicitly Essens et al.’s CTEF model, 2005).

Team mental models (TMM) can be defined as structures of knowledge held by members of a team that are developed to describe, explain, and predict their environment, and, consequently, allow them to coordinate their activities, interact with each other and with their environment, and adapt their behaviour to demands coming from the task and other team members (Cannon-Bowers et al., 1993; Rouse & Morris, 1986). TMM are conceived herein as mental representations that are individually held (i.e., there is no “team model” per se) and that are consistent across team members (Cannon-Bowers et al., 1993; Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005). Many researchers have suggested that team members hold more than one mental model, and therefore have emphasized the importance of taking into account multiple types of TMM and their respective impact on team functioning (e.g., Cannon-Bowers et al., 1993; Klimoski & Mohammed, 1994; Mathieu et al., 2000; Rentsch & Hall, 1994). Mathieu and his collaborators (2000; Mathieu, Maynard, Rapp, & Mangos, 2010) propose that there are two types of TMM that essentially represent two domains of knowledge, one that is task-related (knowledge about the task, task environment, equipment, procedures, etc.), and one that is team-related (knowledge about team members and their interactions). However, Cannon-Bowers et al. (1993) see the relevance in distinguishing four different types of mental models: technology/equipment models, job/task models, team interaction models, and team models. In this taxonomy, technology/equipment models include knowledge on how to operate equipment, possible failures and system limitations; job/task mental models comprise information such as task procedures and strategies, potential contingencies and environmental constraints; team interaction models refer to knowledge about roles and responsibilities, role interdependencies, information flow, etc.; and team models contain information about teammates’ knowledge, expertise, abilities, preferences, etc.

The purpose of this study is to investigate whether the enhancement of TMM, more specifically, task models and team interaction models, has a beneficial effect on team processes and performance. The task and team interaction domains of knowledge were selected as a focus for the present study because they appear to be the most worthwhile targets for training. Indeed, as Cannon-Bowers et al. (1993) point out, equipment mental models are highly stable as individuals are likely to use similar equipment across missions to perform their tasks. In contrast, team mental models are very unstable, as they will change every time the team’s composition is altered. This is particularly evident in military environments, where teams change on a regular

basis due to personnel turnover (e.g., postings and deployments). Examining TMM is also cumbersome as it requires team members to possess extensive knowledge of each other, and to have worked together over a significant period of time (see, e.g., Espevik, Johnsen, Eid, & Thayer, 2006). Cannon-Bowers et al. suggest that task models and team interaction models are moderately stable, with some parameters stable and some parameters varying across situations. Therefore, task and team interaction mental models appear to be the most susceptible to benefit from training, in terms of transfer potential and feasibility. These mental models are also the most commonly studied empirically (see, e.g., Fleming, Wood, Ferro, Bader, & Zaccaro, 2003; Lim & Klein, 2006; Mathieu et al., 2000; Mathieu et al., 2005; Mathieu et al., 2010; Smith-Jentsch, Mathieu, & Kraiger, 2005). In previous studies, often no attempt was made to directly manipulate TMM; rather, correlations were examined between TMM and experimental manipulations or between TMM and team effectiveness. Thus, the novelty of the present study lies in its attempt to directly impact TMM. Few such efforts are reported in the literature, with one study directly manipulating TMM through cross-training (Marks, Sabella, Burke, & Zaccaro, 2002) but, in that study, only team interaction mental models were of interest. In the present study, direct manipulation of TMM is attempted by assigning teams to one of three learning conditions: a condition with additional information on the task, a condition with additional information on team interaction, and a control condition with no additional information.

In the last ten years, significant research effort has been put towards understanding the role of TMM on team functioning. A number of studies have provided evidence supporting the long-held belief that TMM have a positive impact on team performance (e.g., Edwards et al., 2006; Marks et al., 2002; Marks, Zaccaro, & Mathieu, 2000; Rentsch & Klimoski, 2001). As summarized by Mathieu et al. (2010), findings have shown that team performance is more accurately predicted either by team-related mental models (Mathieu et al., 2000), task-related mental models (Lim & Klein, 2006; Mathieu et al., 2005), or by the interaction between the two types of mental models (Mathieu et al., 2010; Smith-Jentsch et al., 2005). As pointed out by Mathieu et al. (2010), while not completely consistent, these findings bring additional support to the notion that TMM contribute positively to teamwork, and they also suggest that multiple TMM "do not operate in a vacuum, but combine in unique ways to influence team outcomes" (p. 35).

Performance is a global indicator of effectiveness that does not necessarily reveal the whole picture of how teams go about completing their mission. Empirical evidence suggests that the link between TMM and performance is partially or completely mediated by team processes (e.g., Marks et al., 2002; Mathieu et al., 2000; Mathieu et al. 2005). Therefore, it is important to include both outcome (i.e., performance) and process measures in the investigation of teamwork. In the present study, in addition to measures of team performance, measures of coordination and communication are used to assess the impact of TMM enhancement on team processes. Coordination is commonly measured through observers' ratings or objective metrics derived from the task environment used. With both approaches, coordination has been found to be linked to team effectiveness, with better coordination being associated with better performance (e.g., Grote, Kolbe, Zala-Mezö, Bienefeld-Seall, & Künzle, 2010; Lafond, Jobidon, Aubé, & Tremblay, 2011; Marks et al., 2002; Marks & Panzer, 2004). Communication is often assessed through qualitative content analysis, but can also be quantified through physical measures such as frequency of communication and time spent on communication (e.g., Kiekel, Cooke, Foltz, Gorman, & Martin, 2002; Kiekel, Cooke, Foltz, & Shope, 2001). Empirical findings have shown inconsistent links between physical measures of communication and team functioning. Several studies have reported evidence of a positive link between frequency of communication and team performance

(e.g., Brannick, Roach, & Salas, 1993; Foushee & Manos, 1981; Lafond et al., 2011; Sexton & Helmreich, 1999; Svensson, 2002) while others find a negative correlation (e.g., Cannon-Bowers, Salas, Blickensderfer, & Bowers, 1998; Volpe, Cannon-Bowers, & Salas, 1996).

The effect of TMM on team effectiveness is not a general, globalized effect but one that can depend on task characteristics. Several studies on TMM have included manipulations of characteristics of the task environment, such as workload (Stout, Cannon-Bowers, Salas, & Milanovich, 1999), novel vs. routine situations (Marks et al., 2000) and degrees of urgency (Fleming et al., 2003). The aim of these manipulations was to investigate whether task characteristics can moderate the impact of knowledge or mental models on team effectiveness. In the present study, task complexity is varied to investigate whether it moderates the effect of TMM on team effectiveness. This is achieved by manipulating environmental dynamics, which affect the transparency of courses of action (COA).

Studies investigating means to optimise teamwork are clearly relevant to the defence environment. The present study aims to uncover whether (and under which task circumstances) the enhancement of task and team interaction mental models could serve such a purpose. If our results demonstrate an improvement in team effectiveness, task and team interaction mental models would be promising candidates to target in the context of learning and training efforts as they are moderately stable across situations. Thus, the potential contribution of this study would not only include the furthering of knowledge on teamwork and TMM, but could have a more immediate and direct impact on team effectiveness in CF operations.

2 Method

2.1 Participants

Fifty-four adult participants took part in this study, 22 females and 32 males, for a total of 27 two-person teams. Participants were either civilians or military personnel (34 civilians and 20 military) who were recruited locally through advertisement. All participants were naïve with respect to the objectives of the study. This study was approved by the DRDC Human Research Ethics Committee (HREC).

2.2 Apparatus

The experiment was conducted on standard personal computers running the C^3Fire microworld simulation software (Granlund, 1998). The C^3Fire microworld is a computer-controlled simulation of forest firefighting. C^3Fire runs in a client-server configuration, each participant playing the simulation on a separate computer, in individual rooms. A mouse and keyboard are used as input devices. Every event and action in an experimental trial generates time-stamped data that C^3Fire automatically records and stores. In this study, participants communicated verbally via headsets, supported by the TeamSpeak software (TeamSpeak Systems, Krün, Germany).

In C^3Fire, the action takes place on a geo-spatial map displayed on a 40 cells × 40 cells grid (*Figure 1*). This matrix represents an area that consists of five interacting simulation layers.

1. *Map layer*. The map in C^3Fire is represented by a background image that is defined in a session configuration file.

2. *Geographical object layer*. The C^3Fire environment is built up of different kinds of objects displayed on the map (e.g., trees, lakes, houses). A cell can contain any one of these objects but only one object can be displayed in a cell. Each object has configurable ignition and burning times. The geographical objects can be used to create different priorities (e.g., houses vs. large forest areas or plains).

3. *Fire layer*. Each cell of the 40 × 40 matrix has its own fire simulation, and together they represent the fire. The fire's point of origin is determined in the session configuration, but how the simulation develops depends on the fire location, proximity to different types of objects, and wind properties. As the fire develops, it can be in one of five states: clear, on fire, closed-out, burned-out or fire break. A clear cell indicates that a fire has not yet started in that cell, and spontaneous ignition (i.e., not preset by the experimenter) is possible only if a neighbouring cell is already on fire. When on fire, a cell takes on the colour red and one of the team’s aims is to extinguish as many burning cells as possible. When extinguished, a cell becomes closed out and takes on the colour brown. A burned out cell signifies that it has burned totally before being extinguished and can no longer be extinguished nor re-ignite, and takes on the colour black. When a fire break is created, the cell turns to grey and it can no longer ignite.

4. *Weather layer*. This layer determines the strength and direction of the wind. As the wind speed increases, the fire spreads faster in the same direction as the wind blows and spreads slower in the opposite direction.

5. *Units layer*. There are several classes of units in C3Fire, three of which were used in this study: firefighting units that extinguish fires, water units that supply water to firefighting units, and fire break units that can block the spread of the fire. All three types of units are represented by digits of different colours: red for firefighters, blue for water tankers, and grey for fire break units. Participants control a unit's movement by clicking on it, dragging it to the projected position, and then dropping it. After the manoeuvre, the intended position appears at the drop position and the unit will start moving towards it. When a unit moves, its number appears in white colour on the destination cell.

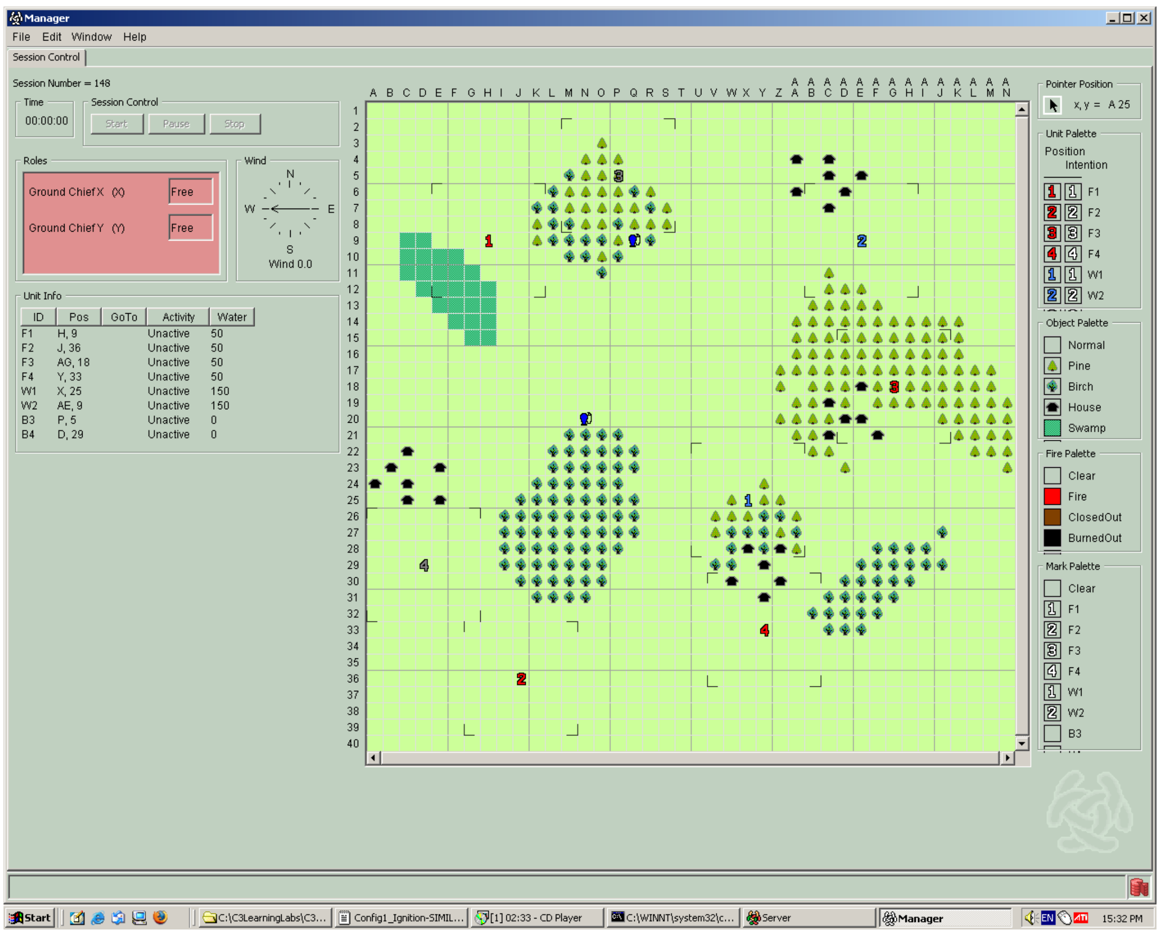

Figure 1. Example of the C3Fire interface that includes area map and control displays. Cells are identified by [letter, number] coordinates (e.g., [B, 2]).

In the current study, the C3Fire configuration settings were selected so that the point of origin of the fire (upper right quadrant of the map) and the initial position of all units was kept constant at the onset of each simulation run. While playing the stimulation, each team member could see the fire, geographical objects and the units he/she controlled. However, a team member could not see

the other team member's units unless these units were in close proximity of one of the units he/she controlled. This visible area (or "visual field") was set to a 7 × 7 grid centered on the unit. The total time needed for a firefighter to complete a mobilization / firefighting / demobilization cycle was set to 10 seconds (1 second to mobilize, 8 seconds to fight the fire at the rate of one unit of water per second, and 1 second to demobilize). Firefighters and water tankers had the capacity to hold a maximum of 50 and 150 units of water, respectively, and refill at the rate of 10 and 25 units of water per second, respectively. The time required for a fire break unit to create a fire break was set to 10 seconds, with no delay for mobilization and demobilization. The moving speed of each type of unit was also predetermined. It took 5 seconds for firefighters and water tankers to move from one cell to an adjacent cell, whereas fire breakers made one move every 4 seconds.

The time taken by the fire to ignite a particular cell varied as a function of the ignition speed of the object it contained and the wind speed. In simulation runs with light wind speed, the wind speed value was set to 1, which corresponds to wind blowing at 0.15 m/s, whereas in runs with high wind speed (14.5 m/s) the value was set to 7. The object ignition speed was dependent on the fire spread factor attributed to each type of object. The fire spread factor for swamps and lakes was always set to 0 so that they would not ignite. In simulation runs where ignitable objects had identical ignition speeds, plains, birches, and pines all had a spread factor of 1. In simulation runs where ignitable objects had different ignition speeds, plains had a spread factor of 1 but birches and pines had a factor of 2, making them ignite two times slower than plains. An equation embedded in C^{3}Fire determined the exact speed at which the fire spread in all directions (horizontally, vertically, and diagonally) by taking into account the initial ignition time (which was set to 37 seconds), the wind speed value, and the fire spread factor. Once ignited, it took 60 seconds for a cell to burn out regardless of the wind speed or the type of object it contained.

2.3 Experimental design

This study comprised one between-subject experimental variable (learning condition) and three within-subject moderator variables (wind speed, object ignition speed and repetition).

Teams were subjected to one of three learning conditions that varied based on the nature of the information given by the experimenter prior to the start of the experiment. In the first learning condition (*task*), teams received general information to enhance their mental model of the task in the C^{3}Fire environment (fire and wind dynamics, e.g., how the wind can affect the spread of the fire). In the second learning condition (*team*), teams were given information to enhance their mental model of team interaction, i.e., each team member's roles and how these roles can impact firefighting. In the third training condition (*control*), teams were given no additional information.

Teams completed four different C^{3}Fire scenarios that varied based on wind speed and object ignition speed. Wind speed was set to be either high or light. High wind focuses the spread of the fire in one direction, compared to a light wind speed where the fire spreads more evenly around the point of origin. High wind speed therefore should establish a more transparent COA in firefighting strategy. Object ignition speed was set to be either the same or different; that is, in different scenarios, one type of object either ignited faster or at the same speed as other objects. Different ignition speed therefore should also establish a clearer firefighting strategy. Finally, each scenario was presented twice consecutively to investigate learning effects.

2.4 Procedure

Participants were asked for their written consent before participating in the study. They were randomly assigned to two-person teams, with one participant in charge of four firefighting units and the other controlling two water tanks and two fire break units. The experiment was run in a single 3-hour session that included a training session and an experimental session. The 15-minute training session included a first phase (without fire) where the experimenter familiarized participants with the various features of C^3Fire over the headsets, and a second phase (with fire) during which participants practiced moving their units around and fighting the fire. Following the training session, teams were randomly assigned to one of the three learning conditions (task, team or control) and the information pertinent to the task and team learning conditions was given to them on a separate sheet (see **Annex A** for the basic instructions, and **Annexes B** and **C**, respectively, for supplemental information). Teams in all learning conditions shared the same task goal, that is, to save as many houses as possible and to limit as much as possible the number of burnt out cells.

The experimental session consisted of eight scenarios; the four scenarios with different environmental dynamics (2 wind × 2 ignition) were presented twice, consecutively, to each team. The order in which teams completed the scenarios was counterbalanced to limit order effects. Scenarios had a duration of 10 minutes, and were separated by 5-minute breaks.

2.5 Dependent variables

2.5.1 Team performance

The performance measures related to the team's goals, namely, saving as many houses as possible and limiting the number of burnt out cells. Performance was quantified as the number of saved houses and the number of saved cells in relation to the number of houses and cells, respectively, which would burn in the worst-case scenario (i.e., in the 10-minute scenario if no firefighting action was taken)[1]. Therefore:

Proportion of saved houses = number of houses saved / number of burnt-out houses in worst-case scenario

Proportion of saved cells = number of cells saved / number of burnt-out cells in worst-case scenario

[1] The "worst-case" number of cells burnt out and saved was calculated by taking into consideration the various states in which cells can be. That is, the worst-case number of *burnt-out* cells was defined as the sum of cells that were on fire and burned out at the end of a scenario that was run without any firefighting intervention (from firefighter or fire break units). Cells *saved* included cells that were clear, extinguished as well as cells where a fire break was built. The number of cells saved was calculated by subtracting the number of cells on fire and burned out at the end of a played scenario from the number of worst-case burnt-out cells.

The rationale for quantifying performance as a proportion was that, depending on the scenario, a different number of houses and cells burned out if no action was taken[2].

2.5.2 Team processes

2.5.2.1 Coordination

Coordination was evaluated based on the time firefighting units spent without water, and the time units spent being idle. According to Crowston (1997), these measures correspond to coordination mechanisms that serve to manage dependencies between task and resources for the former measure, and task and actor's time for the latter measure. They can therefore provide good indicators of the efficiency in managing key processes in C^3Fire, that is, the water refill process through which the firefighters' need in water is synchronized with the supply from water tankers, and the monitoring process through which idle units are identified in a timely manner and given new activity orders. These two measures were calculated as follows:

Water refill effectiveness = average time firefighters spent without water / total scenario time

Monitoring effectiveness = average unit idle time / total scenario time

2.5.2.2 Communication

Time spent communicating was obtained by removing pauses, silences, and time between scenarios from each team's TeamSpeak audio recording. As a certain number of teams finished some scenarios early (i.e., they did not play the full 10 minutes) time on communication was quantified as the proportion of time spent communicating to the total time played (for all eight experimental scenarios).

[2] This "worst-case scenario" has been previously suggested as a baseline against which team processes and performance variables are measured (see, e.g., Lafond et al., 2011). For instance, if a team let 10 houses burn down in a scenario where 15 houses will burn out if no firefighting action is taken, compared to a condition where 20 houses will burn out, the proportion will reflect the better performance in the former team even if the actual number of houses burned is the same in both scenarios (i.e., 10 houses). These contextualized measures thus allowed normalizing comparisons between conditions, and provided a more accurate picture of team effectiveness than absolute measures.

3 Results

Measures of performance, coordination and communication were computed based on data extracted from the C^3Fire and TeamSpeak recordings.

3.1 Team performance

A series of four-way mixed univariate analyses of variance (ANOVAs) were conducted on the performance measures with learning as the between-subjects variable, and wind, ignition, and repetition as the within-subjects variables. Only relevant results are reported for the sake of simplicity.

Because the dependent variables were proportions (i.e., bounded at 0 and 1), which can lead to distortions in the pattern of means, the data were transformed using a logit transformation (Cohen, Cohen, West, & Aiken, 2003) prior to running the ANOVAs. The mean proportions obtained from converting the transformed mean logits back to proportions are reported (with 95% confidence intervals in brackets, Howell, 2010).

Importantly, no significant main effect of learning condition was found on performance, irrespectively of whether performance was quantified as the proportion of saved cells or the proportion of saved houses.

The effect of the moderator variables (wind, ignition, and repetition) were as expected, indicating that high wind and different ignition improved performance, and that performance also improved with repetition. More specifically, there were significant main effects of ignition, wind and repetition on the mean proportions of cells saved, $F(1, 24) = 12.72$ to 31.43, all ps $\leq .002$[3-4]. The teams saved a significantly greater mean proportion of cells under the high wind condition (.61 [.48, .72]) than they did under the light wind condition (.35 [.29, .40]). They also performed significantly better under the different ignition condition (.54 [.44, .63]) than they did under the same ignition condition (.41 [.33, .50]). Lastly, they saved a significantly greater mean proportion of cells at Time 2 (.52 [.42, .61]) than they did at Time 1 (.43 [.35, .52]). Similarly, there were significant main effects of ignition and repetition on the mean proportions of houses saved, $F(1, 24) = 9.53$ to 15.70, all ps $< .005$[5]. That is, the teams saved a significantly greater mean proportion of houses under the different ignition condition (.96 [.92, .98]) than they did under the same ignition condition (.88 [.80, .93]), and they also performed significantly better at Time 2 (.95 [.91, .97]) than they did at Time 1 (.91 [.83, .95]).

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[3] A significant four-way interaction effect qualified these main effects, $F(2, 24) = 3.68$, $MSE = 0.42$, $p = .041$, $\eta_p^2 = .23$. However, the pattern of cell means alluded to ordinality. In such cases, Keppel (1991) states the main effects may be interpreted as main effects.

[4] Ignition: $F(1, 24) = 31.43$, $MSE = 1.97$, $p < .001$, $\eta_p^2 = .57$; wind: $F(1, 24) = 13.60$, $MSE = 0.95$, $p = .001$, $\eta_p^2 = .36$; and repetition: $F(1, 24) = 12.72$, $MSE = 0.50$, $p = .002$, $\eta_p^2 = .35$.

[5] Ignition: $F(1, 24) = 15.70$, $MSE = 5.16$, $p < .001$, $\eta_p^2 = .40$; and repetition: $F(1, 24) = 9.53$, $MSE = 2.98$, $p < .005$, $\eta_p^2 = .28$.

3.2 Team processes

For the same reasons that team performance measures were transformed, coordination and communication data were also transformed using a logit transformation (Cohen et al., 2003) prior to running the ANOVAs.

3.2.1 Coordination

A series of four-way mixed univariate ANOVAs were also conducted on the coordination measures with learning as the between-subjects variable, and wind, ignition, and repetition as the within-subjects variables.

3.2.1.1 Water refill effectiveness

The ANOVA did not yield significant effects of learning condition, environmental dynamics or repetition on the mean proportions of time the firefighting units spent without water.

3.2.1.2 Monitoring effectiveness

Again, there was no significant effect of learning condition on monitoring effectiveness as quantified by idle time of firefighters and fire break units.

Wind speed and repetition did have a significant effect on idle time of firefighters and fire break units, $F(1, 24) = 10.14$ to 36.93, all ps $\leq .004$[6-7]. Specifically, the firefighting and fire break units spent a significantly smaller mean proportion of their time idle under high wind (.62 [.57, .67] and .60 [.56, .65], respectively) than they did under light wind (.70 [.66, .73] and .69 [.64, .73]). Furthermore, at Time 1 they spent a significantly smaller mean proportion of their time idle (.65 [.61, .69] and .62 [.58, .66]) than they did at Time 2 (.67 [.63, .71] and .67 [.62, .72]).

3.2.2 Communication

A one-way ANOVA was performed on the time spent on communication with learning as a between-subjects variable.

The ANOVA did not yield a significant effect of learning condition on the proportion of time spent on communication. However, as can be seen in *Figure 2*, there is a trend in the data suggesting that teams who received additional information about task or team interaction spent

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[6] Note that a significant wind-by-repetition interaction effect qualified these main effects, $F(1, 24) = 8.63$, $MSE = 0.05$, $p = .007$, $\eta_p^2 = .27$. Given the ordinal nature of this interaction, we can interpret the main effects without caution (Keppel, 1991).

[7] For firefighters, effects of wind: $F(1, 24) = 36.93$, $MSE = 0.19$, $p < .001$, $\eta_p^2 = .61$; and repetition: $F(1, 24) = 10.14$, $MSE = 0.06$, $p = .004$, $\eta_p^2 = .30$. For fire break units, effect of wind: $F(1, 24) = 30.76$, $MSE = 0.22$, $p < .001$, $\eta_p^2 = .56$; and repetition: $F(1, 24) = 27.00$, $MSE = 0.09$, $p < .001$, $\eta_p^2 = .53$.

more time communicating than teams who received no additional information (.35 and .37 vs. .28).

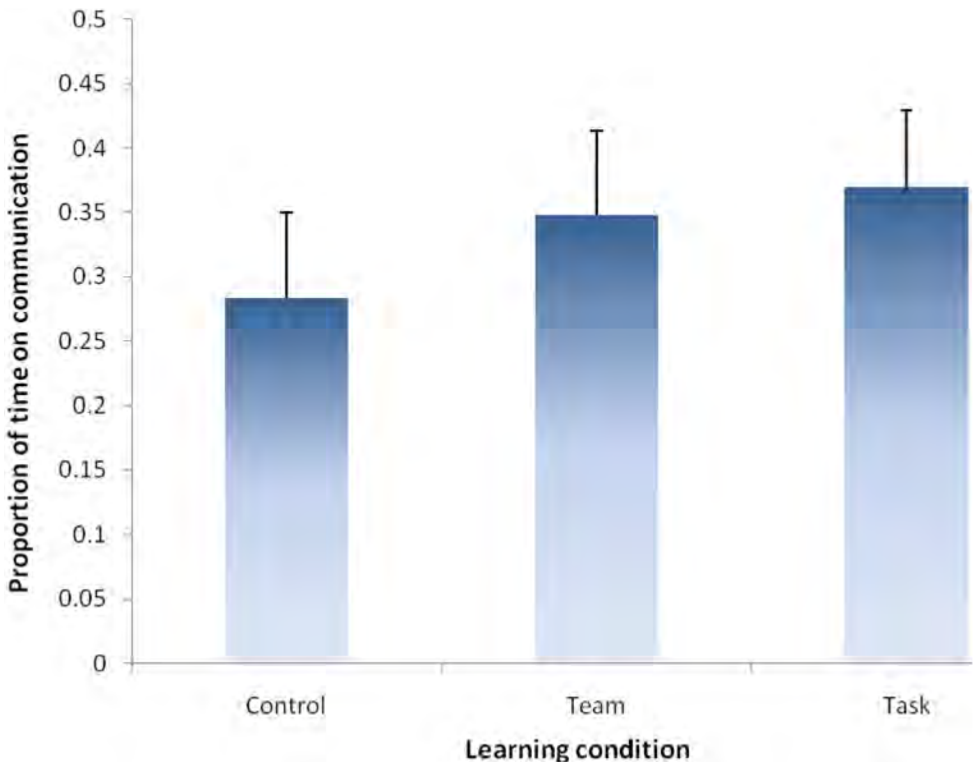

Figure 2. Proportion of time spent on communication to the total play time as a function of learning condition. Error bars represent standard error.

4 Discussion

The success of CF operations relies on team members working cooperatively towards shared goals. It is commonly recognized that shared knowledge contributes positively to team functioning and, as such, team mental models have been the focus of many research endeavours (e.g., Edwards et al., 2006; Marks et al., 2002; Mathieu et al., 2010; Rentsch & Klimoski, 2001; Stout et al., 1999). The objective of the present study was to investigate whether enhancing mental models of task or team interaction improved team effectiveness in dynamic situations. The enhancement of mental models of task and team interaction was attempted by subjecting teams to different learning conditions prior to the execution of the task. In the task condition, teams were informed about environmental dynamics that were pertinent to their firefighting task. In the team condition, teams were briefed on the roles of each team member and on possible interaction strategies. These conditions were contrasted with a control condition in which no additional information was provided.

Previous studies have proposed that task characteristics moderate the relationship between mental models and team effectiveness (e.g., Marks et al., 2000; Stout et al., 1999). The present study therefore also included a manipulation of task complexity that varied the transparency of the COA for optimal task performance. This was achieved by varying wind and object ignition speed; that is, a clearer COA should be established in conditions of high wind and in conditions where different objects ignited at different speed. Indeed, the results of the present study showed that this task manipulation was successful: better performance and monitoring effectiveness was observed under high wind and different ignition speed conditions, the conditions associated with a more obvious COA.

However, despite the effective task complexity manipulation, the results did not show a significant effect of learning condition on team effectiveness. Teams in all three learning conditions performed equally well in terms of extinguished cells and houses, independently of task complexity. Similarly, the learning condition did not significantly affect the monitoring effectiveness of the teams, as quantified by idle time of firefighters and fire break units. Whereas these findings may appear to suggest that mental models do not affect team performance and coordination, many previous empirical studies have shown that various types of mental models have a positive effect on team effectiveness, either directly or mediated through team processes (e.g., Fleming et al., 2003; Marks et al., 2000; Mathieu et al., 2000; Mathieu et al., 2005; Mathieu et al., 2010). A more likely explanation for the non-significant findings is that the task and team learning conditions used in this study did not sufficiently enhance the teams' mental models to observe an effect on team effectiveness.

In line with the performance and coordination results, learning conditions also did not significantly affect time on communication. However, a trend in the data suggests that teams with additional information on team interaction or task spend more time on communication. A positive relationship between team mental models and communication processes has been assumed for over a decade (e.g., Kraiger & Wenzel, 1997; Stout et al., 1999) and indeed, team mental models have been shown to be positively related to communication. For instance, Marks et al. (2000) showed that development of similar team interaction mental models among team members enhances communication processes (see also Hirschfeld, Jordan, Feild, Giles, & Armenakis, 2006; Mathieu et al., 2000).

4.1 Recommendations and conclusion

This study was a first attempt at investigating the effect of enhancing TMM on team effectiveness. Unfortunately, we can draw only limited conclusions as to the impact of additional pre-experimental information about the task or team interaction on team functioning. The lack of significant differences between the three learning conditions suggests that the difference among conditions may not have been sufficiently salient. One explanation for this is that in C^3Fire, the basic information on how to play the game may provide enough knowledge on roles and task environment that the additional information provided in the task and team interaction conditions may not have afforded a strong enough advantage to impact team effectiveness significantly.

Different avenues are possible to improve upon the design and analyses reported here. For instance, more knowledge on task and team interaction could be given to participants to make the conditions more distinctive, or a similar design could be implemented in a task environment that does not require as much basic knowledge as C^3Fire does. In addition, including a measure of team knowledge or mental models in the design of future studies would provide valuable information on the content of mental models, and allow for better assessment of any change in the models following the experimental manipulation. Some limitations are inherent to team research, especially in complex and dynamic environments. That is, both the presence of several people and the dynamic nature of the task increase noise and variability in the data. Therefore, future experiments should include a greater number of participants in each experimental condition. This would allow reaching an adequate level of statistical power, and might provide a more definitive picture of the effect of TMM enhancement on team performance and team processes. Further analyses could inform us, among other things, on communication patterns through analysis of communication content, and on whether there are differences between civilian and military teams with regards to team performance and communication.

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Annex A Basic instructions to participants

A.1 Instructions for Ground Chief X

The goal of this experiment is to look at how people cooperate and make decisions in complex and dynamic environments. You will be engaging in a fire-combat simulation using the C^3Fire microworld. The C^3Fire environment is represented by an area map on a 40 x 40 matrix populated with geographical objects (e.g., vegetation, houses). The role of the houses is to make some areas more important to save than others. At one point in time a fire will start in some location. As the fire develops, it can be in one of four states: clear, on fire, extinguished (closed out), or burned out (see *Figure A*).

Figure A. Possible states of the fire.

<u>Your objective</u>: To save as many houses as possible and to control the fire as much as possible.

There are three classes of units in the C^3Fire that you can control: fire trucks, water tanks, and fire break units. Fire trucks are used to fight fires, water tanks provide water supply to fire trucks, and fire break units serve to stop the fire from spreading. All types of units can be used to search the area for new fires. You will be assigned to fire-fighting duties (controlling fire trucks). You will control the movement of a unit by clicking on a target unit on the map, dragging the unit to the projected position, and then dropping the unit. After the manoeuvre, the intended position will appear at the drop position (the unit's number in white) and the unit will start to move towards it. **Moving units and activities (e.g., fire-fighting) take time. You have to wait for the unit to reach its destination or for the cell to change colour (e.g., from red to brown) before tasking the unit to a new activity**. You will find information such as the current activity of each unit, the water level, and the wind on panels next to the map. (Note that the arrow on the wind panel indicates from where the wind is coming.)

During the simulation, you will see the fire, geographical objects and the units under your control. Units controlled by your teammate will only be visible in a restricted 7 x 7 visual field, and will disappear once they are out of one of your unit's visual field. You will be able to communicate with your teammate through headphones using TeamSpeak software. You will be assigned to:

- Ground chief X (fire-fighting duties). You will be responsible for fighting fires using four fire-fighting (FF) units. Each unit will have a finite water supply that will be displayed on the screen. **To fight fires you will need to move a FF unit directly onto a burning cell**, which will trigger a fire-fighting action (just passing on a cell on the way to another cell will not extinguish the fire). Once a FF unit begins fire-fighting, the water supply will diminish over time. To refill your water supply you will need to contact your teammate who will be responsible for providing your FF units with water (WT units). **To refill the water supply, the FF and WT units must be adjacent (i.e., in the next cell on the right, left, up, or down)**. Your teammate will also control two fire break units.

The experiment will begin with a practice scenario, in which you can control your units and communicate with your teammate, and practice your role (e.g., extinguishing fire, creating fire breaks). The practice will be followed by four 10-minute experimental scenarios. After a short break, you will complete four other experimental scenarios, for a total of eight scenarios. There are four different scenarios, and each scenario will be repeated twice, consecutively. A fire will break out at the beginning of each scenario.

If you have any questions about the experiment, the experimenter will be happy to answer them for you.

A.2 Instructions to Ground Chief Y

The goal of this experiment is to look at how people cooperate and make decisions in complex and dynamic environments. You will be engaging in a fire-combat simulation using the C^3Fire microworld. The C^3Fire environment is represented by an area map on a 40 x 40 matrix populated with geographical objects (e.g., vegetation, houses). The role of the houses is to make some areas more important to save than others. At one point in time a fire will start in some location. As the fire develops, it can be in one of four states: clear, on fire, extinguished (closed out), or burned out (see *Figure A*).

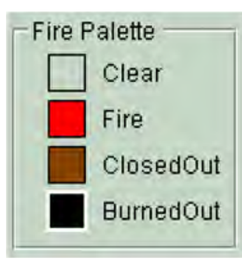

Figure A. Possible states of the fire.

Your objective: To save as many houses as possible and to control the fire as much as possible.

There are three classes of units in the C^3Fire that you can control: fire trucks, water tanks, and fire break units. Fire trucks are used to fight fires, water tanks provide water supply to fire trucks, and fire break units serve to stop the fire from spreading. All types of units can be used to search the area for new fires. You will be assigned to supply and fire breaking duties (controlling water tanks and fire break units). You will control the movement of a unit by clicking on a target unit on the map, dragging the unit to the projected position, and then dropping the unit. After the manoeuvre, the intended position will appear at the drop position (the unit's number in white) and the unit will start to move towards it. **Moving units and activities (e.g., creating fire breaks) take time. You have to wait for the unit to reach its destination or for the cell to change colour (e.g., from red to brown) before tasking the unit to a new activity**. You will find information such as the current activity of each unit, the water level, and the wind on panels next to the map. (Note that the arrow on the wind panel indicates from where the wind is coming.)

During the simulation, you will see the fire, geographical objects and the units under your control. Units controlled by your teammate will only be visible in a restricted 7 x 7 visual field, and will disappear once they are out of one of your unit's visual field. You will be able to communicate with your teammate through headphones using TeamSpeak software. You will be assigned to:

- <u>Ground chief Y (water supply and fire break duties)</u>. You will control two water tank (WT) units and two fire break (FB) units. Each WT unit will have a certain supply of water that will be displayed on the screen. Your teammate will have four fire-fighting (FF) units. Your task is to supply FF units with water. **To supply water to FF units you need to move and position a WT unit next to a FF unit (i.e., in the next cell on the right, left, up, or down)** which will trigger a water-refilling process. Once the refill process is started, the water supply of the WT unit will diminish. When the water supply is low, you will need **to refill your water supply by moving a WT unit next (right, left, up, or down) to one of the sources of water** displayed on the map. FB units can be used to block the spread of the fire. **To create a fire break, you need to position the FB unit on the cell** where you want to set a fire break, wait until the unit reaches that destination, and then double click on the left button of the mouse. To create a fire break in a new cell, you must move the FB unit to that cell and double click again. A fire break can only be created on a cell that is clear, i.e., one that has not caught fire yet.

The experiment will begin with a practice scenario, in which you can control your units and communicate with your teammate, and practice your role (e.g., extinguishing fire, creating fire breaks). The practice will be followed by four 10-minute experimental scenarios. After a short break, you will complete four other experimental scenarios, for a total of eight scenarios. There are four different scenarios, and <u>each scenario will be repeated twice, consecutively</u>. A fire will break out at the beginning of each scenario.

If you have any questions about the experiment, the experimenter will be happy to answer them for you.

Annex B Additional information in task condition

In C[3]Fire, the spread of the fire is influenced by the direction and speed of the wind, and the ignition time of the various geographical objects. Ignition time refers to the time it takes for a cell to catch fire. Different objects may have different burning qualities (i.e., some may ignite faster or slower than others). Various combinations of wind speed and direction with ignition times will create fires of different shapes and speeds. For instance, when the wind is strong the fire spreads faster in the same direction as the wind blows. Similarly, in a scenario where trees burn slower than plains, the fire will spread unevenly since it will take more time to burn through wooded areas (see *Figure B* for examples).

Figure B. Examples of various shapes of fire.

To fight fires successfully (with minimal damage to houses), it is important for both you and your teammate to use the information about the environment to understand the situation, and adapt the way you fight the fire accordingly. You will have cues about the wind speed and ignition time by noticing how the fire spreads (e.g., Is it spreading faster in one direction? Does it slow down when it reaches a forest?).

Annex C Additional information in team condition

In C[3]Fire, you can coordinate with your teammate and combine your respective roles to fight the fire more effectively. Each type of unit plays a role in fighting the fire, especially fire fighting (FF) and fire break (FB) units. FF units have a direct impact as they extinguish fire, whereas FB units can influence and shape the spread of the fire by blocking its way and can be used to protect certain areas. Therefore, you and your teammate can coordinate the actions of your respective FF and FB units and tailor your strategies based on the situation you are facing. For instance, you can adapt your fire-fighting strategy and coordinate FF and FB units in different ways if the fire develops in the shape of a circle than if it develops in a line (see *Figure B* for examples).

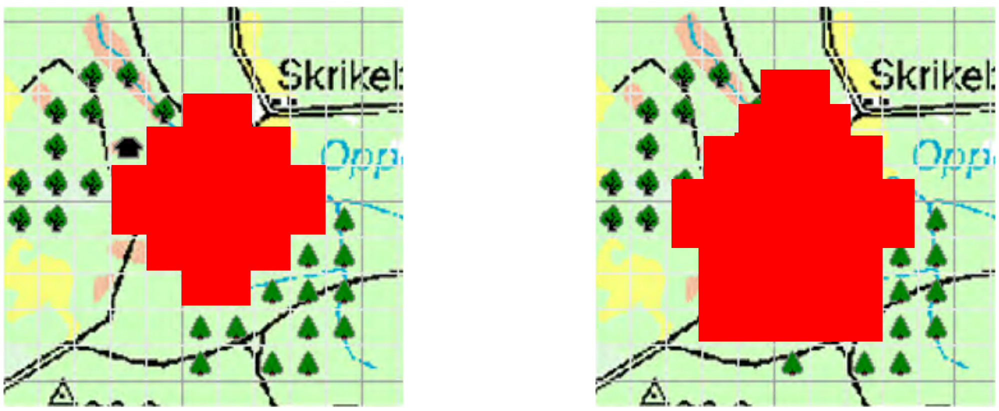

Figure B. Examples of various shapes of fire.

To fight fires successfully (with minimal damage to houses), you and your teammate must cooperate and exchange information. It is important for both of you to allocate your units in the best possible way, so that the combined effort of FF and FB allows you to control the fire more effectively.

This is an example of a paragraph. The paragraph does not say anything important, but does provide a visual of what a paragraph looks like. Below is a sample of an annex equation that has been inserted using the DRDC toolbar:

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List of acronyms

ANOVA	Analysis of variance
CF	Canadian Forces
COA	Courses of action
DRDC	Defence R&D Canada
FB	Fire breaks
FC	Forces canadiennes
FF	Firefighters
HREC	Human Research Ethics Committee
MMC	Modèles mentaux communs
MSE	Mean square error
RDDC	R & D pour la défense Canada
TMM	Team mental models
WT	Water tankers

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(U) The success of Canadian Forces operations relies on team members working cooperatively towards shared goals. It is commonly recognized that some form of shared knowledge contributes positively to team functioning, and as such the concept of team mental models (TMM) has been the focus of many research endeavours (e.g., Edwards et al., 2006; Marks et al., 2002; Mathieu et al., 2010). The purpose of this study was to investigate whether enhancing TMM, more specifically task models (knowledge on task procedures and strategies, potential contingencies and environmental constraints) and team interaction models (knowledge about roles and responsibilities, role interdependencies, information flow, etc.) improved team processes and performance in dynamic situations. Fifty−four participants took part in this study, for a total of 27 two−person teams. C3Fire, a simulation of forest firefighting, was used as task environment. Each team was assigned to one of three learning conditions meant to manipulate TMM: task (additional information on environmental dynamics pertinent to the firefighting task), team (additional information on the roles of each team member and possible interaction strategies) and control (no additional information). Task complexity was varied through transparency of courses of action (COA) to investigate whether it moderates the effect of TMM on team effectiveness. Measures of team performance and team processes were gathered. The results showed that the manipulation of task complexity was successful: better performance and coordination were observed in conditions with a more obvious COA. However, there was no significant effect of learning condition on team effectiveness. This study was a first attempt at investigating the effect of enhancing TMM on team effectiveness. Unfortunately, we can draw limited conclusions as to the impact of additional pre−experimental information about the task or team interaction on team functioning. Future plans could include making task and team interaction conditions more distinctive, and adding a measure of team knowledge or mental models to gather valuable information on the content of TMM, and allow to better assess any change in the models following the experimental manipulation.

(U) Le succès des opérations des Forces canadiennes repose sur la capacité des membres de l’équipe à travailler ensemble vers des buts communs. Il est largement reconnu que certaines formes de connaissances communes ont des effets positifs sur le fonctionnement d’une équipe. C’est pourquoi le concept de « modèles mentaux communs » (MMC) a fait l’objet de nombreuses recherches (p. ex., Edwards et coll., 2006; Marks et coll., 2002; Mathieu et coll., 2010). La présente étude a pour but de vérifier si le fait d’améliorer des MMC, plus particulièrement les modèles de tâche (connaissances des procédures et des stratégies associées à une tâche donnée, des imprévus et des contraintes environnementales) et les modèles d’interaction (connaissances des rôles et responsabilités, des interdépendances des rôles, de la circulation de l’information, etc.), contribue à l’amélioration des processus et du rendement collectifs dans des situations dynamiques. Les 54 participants ont été divisés en 27 équipes de deux personnes. C3Fire, un simulateur de lutte contre les feux de forêt, a été utilisé comme tâche expérimentale. Chacune des équipes a été affectée à l’une des trois conditions d’apprentissage pouvant influencer un MMC : tâche (plus d’informations sur la dynamique d’une lutte contre un incendie), équipe (plus d’informations sur les rôles de chacun des membres de l’équipe et sur les stratégies d’interaction possibles) et contrôle (aucune information additionnelle). La complexité de la tâche a été variée par l’entremise de la transparence des plans d’action afin de déterminer si la complexité modérait les effets des

MMC sur l’efficacité collective. Les mesures du rendement et des processus collectifs ont ensuite été recueillies. Les résultats ont révélé que la manipulation de la complexité de la tâche a été fructueuse : un meilleur rendement et une meilleure coordination ont été observés lorsque le plan d’action était plus évident. Par contre, on n’a noté aucun effet de la condition d’apprentissage sur l’efficacité de l’équipe. Cette étude constituait la première tentative visant à déterminer les effets de l’amélioration des MMC sur l’efficacité collective. Malheureusement, les résultats sont peu concluants pour ce qui est des effets de l’ajout de renseignements préexpérimentaux à propos de la tâche ou de l’interaction des membres de l’équipe sur le bon fonctionnement de l’équipe. Il serait intéressant d’inclure dans les futurs travaux de recherche des conditions liées aux tâches et à l’interaction collective plus distinctes et une mesure des connaissances de l’équipe (modèles mentaux) de manière à amasser des données utiles sur le contenu des MMC et d’être en mesure de mieux évaluer tout changement apporté aux modèles à la suite d’une manipulation expérimentale.

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(U) team; team mental model; dynamic situations; team effectiveness; team performance; team processes; coordination; communication; task complexity

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